PEDIGREE SELECTION OF SEED AT THE CHAPMAN AND MERREDIN EXPERIMENT FARMS.

By Geo. L. Sutton.

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"I've seen the largest seed tho' viewed with care
Degenerate, unless the industrious hand did yearly cull the largest."
—*Translation from Virgil's Georgics.*

"Pedigree" or "Pure Line" selection is that system of selection under which the choice is made, not solely because of the attractive appearance of the plant, but because of its ability to transmit its good qualities to the progeny. Such a system requires, and the method of selection ensures, that the qualities sought after shall be hereditary. For this purpose a record of ancestry is essential, hence the use of the term "pedigree."

It was by use of such a system that the late Wm. J. Farrer produced and fixed his productions. This system of selection is probably identical with the "single plant" selection of the Vilmorins, and which became known on the Continent of Europe about the middle of last century as the "Vilmorin" method. It was shown by Vilmorin to be the quickest method of obtaining a pure and uniform strain.

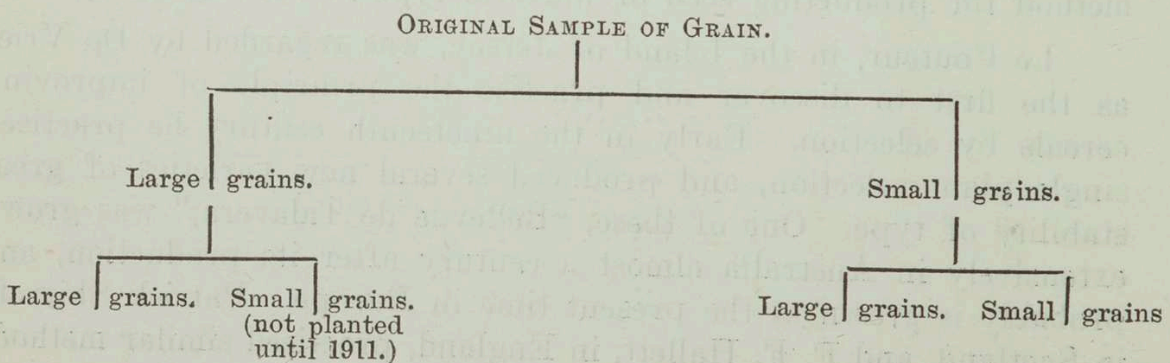
Owing largely to the success which has attended the re-discovery of this method at Svalof, Sweden, in 1891, and its general adoption by the Experiment Stations in Denmark, the system of "pure line" breeding or "pedigree" selection is regarded as the soundest method for producting seed of uniform type of the highest quality.

Le Couteur, in the Island of Jersey, was regarded by De Vries as the first to discover and practise the principle of improving cereals by selection. Early in the nineteenth century he practised single plant selection, and produced several new varieties of great stability of type. One of these, "Bellevue de Talavera," was grown extensively in Australia almost a century after its production, and probably is grown at the present time in Europe. Patrick Shirreff, in Scotland, and F. F. Hallett, in England, practised similar methods about the middle of the same century. The merits of the "single plant" system seem to have been well recognised even at this date, for a recent writer, referring to this period, states: "The method of building up a new variety of cereals from the produce of a single plant seems to have been so well known as to call for no special comment."

Hallett adopted the single ear, and even a selected grain from that ear, rather than a single plant as the basis of his selection, and was apparently the first to apply the term "pedigree" to the seed produced by him. Hallett's aim was to choose the one ear which produced, not only the largest number of kernels, but the best formed ones; an essential feature of his method was repeated selection, and it was remarkable for the minute care and immense amount of work involved.

The selection of the best grains did produce high-yielding plants, but Hallett was not apparently aware that the plump grain of their progeny would not produce higher yielding plants than the plum grain of the progeny of the smaller grain from the same plant.

That this is so is shown by the results of an experiment carried out at the Wagga Experiment Warm, N.S.W., during the years 1902-1911 in continuation of one commenced by Dr. N. A. Cobb in 1895. This experiment was undertaken with the object of determining whether the practice of continually selecting and sowing large grains would result in an improvement in the constitutional character of the grain so as to make the strain more prolific. To test this point, a sample of seed grains was taken and divided by means of a sieve into large and small grains, so that the differences were extreme. These were planted, and the product of these was again similarly divided for the purposes of the experiment. The large grains from the previous generation of large grains were called the large grains from the large-grain row. The product of the small grain was divided, respectively, by a screen into large and small grains. As these grains came from the row planted with small grains, they were respectively known as the *large* and *small* grains from the *small-grain* row, and were used to plant sections (2) and (3). This scheme is shown graphically as follows:—



To eliminate any differences due to peculiar varietal characteristics three varieties were used, and planted under the same conditions; the results obtained are as hereunder:—

Yields of various grades of Seed Wheat at the Wagga Farm, New South Wales.

Year.	Largest grain from "large grain row."				Smallest grain from "large grain row."				Largest grain from "small grain row."				Smallest grain from "small grain row."			
	Allora Spring.	Hudson's E.P. Straw.	White Velvet.	Total.	Allora Spring.	Hudson's E.P. Straw.	White Velvet.	Total.	Allora Spring.	Hudson's E.P. Straw.	White Velvet.	Total.	Allora Spring.	Hudson's E.P. Straw.	White Velvet.	Total.
	oz.	oz.	oz.	lb. oz.	oz.	oz.	oz.	lb. oz.	oz.	oz.	oz.	lb. oz.	oz.	oz.	oz.	lb. oz.
1902 ...	17½	15½	19	3 4	...	...	...	...	16¾	16¾	15	3 0½	6	6	6	1 2
1903 ...	29	25	34	5 8	...	...	...	...	29	30	32½	5 11½	18½	21	13½	3 5
1904 ...	32	30½	28½	5 11	...	...	...	...	31½	34	30½	6 0	15½	18	18	3 3½
1905 ...	29	28	37¾	5 14¾	...	...	...	...	23	30¾	35	5 8¾	15¾	19¾	21½	3 9
1906 ...	33	21½	25	4 15½	...	...	...	...	35½	29½	31¼	6 0¼	18¾	13	18¼	3 2
1907 ...	14	24	15¾	3 5¾	...	...	...	...	19½	20¼	16¾	3 8½	9	11½	9¾	1 14¼
1908 ...	35½	32¾	33	6 5¼	...	...	...	...	33¾	30¾	35½	6 4	22	18¾	17¼	3 10
1909 ...	22¼	32	32½	5 7	...	...	...	...	28¼	32¾	30¾	5 11¾	11	14¾	8	2 1¾
1910 ...	78	61½	54¼	2 2¾	36½	27	29	5 13¼	79	69	58½	12 14½	25¼	27½	16	4 4¾
1911 ...	18¾	23¾	24½	4 3	7	8¾	12¾	1 12½	20¾	20½	23¾	4 1	5½	7¾	10¼	1 7½
Averages	...	...	...	4 10	...	...	...	...	...	...	...	5 14	...	...	...	2 12

If improvement were possible by this method of selection, it is obvious that gradually the yield of seed continuously selected from the large grains would be greater than the yield obtained by continuously using the small seeds.

The results show that this is not so and that the mechanical selection does not effect an improvement in the constitutional character of the grain. If it were otherwise, it would be found in 1909 that the seed which was the progeny of continuously selected best—*i.e.,* large grain for eight years would produce more prolific plants than similarly sized seed, which was the grain obtained as the result of using continuously the worst (smallest) grain for eight years. The average and final results show that this is not the case. The yields from plump grain from either source are, approximately, the same, though slightly in favour of the large grain, which was the progeny of previously selected small grain.

From these results, it appears evident that the marked benefit due to the selection of large grains for seed, reaches its maximum at once, as the immediate result of such selection. The increased yield due to the planting of large grains is not due to any superior constitutional character of the grain, but rather because the larger grains give the young plant a better and more vigorous start in life, a factor which must be considered of very great importance, and of which advantage should be taken.

There is little doubt that selection in some form or other has been practised right down through the ages of agricultural development. Darwin has stated that the improvement of rice by selection was practised in China thousands of years ago, and Virgil refers to the intentional saving of the best grains for a succeeding sowing. It is probable that the earliest system of selection adopted was that under which the largest grains were chosen and planted, and this followed by that under which ears were selected each year in the field in order to provide seed for a nursery plot in which to raise seed for a succeeding main crop. Some farmers still practice this method. An advanced plan is that of making a selection of ears each year from the nursery or elite plot. This system is known as Mass Selection, and is still practised, though to a decreasing extent. Mass selection was the method in general use during the latter half of the past century, and was in vogue at Svalof until 1892, when the method of "single plant" selection was rediscovered. By its use Rimpau, in Germany, produced the superior strain of Rye known as "Schlanstedt." Until the time it was superseded in favour of "single plant" selection, the Mass Selection method was used by Louis de Vilmorin in connection with the improvement of Sugar Beet, and it resulted in a large increase in the amount of sugar produced per acre . . . . Mass selection certainly has advantages, but as was found at Svalof, it has the disadvantage that it does not make for uniformity, and as all the benefits to be desired from Mass selection, together with the added one of uniformity, can be achieved equally as well, more quickly and with more certainty by "pedigree" or "single plant" selection, the latter method is becoming more and more generally adopted.

The practice of growing pedigree selected seed at the Chapman and Merredin Farms was commenced in 1912, the season following the arrival of the writer in this State.

The object of the selection work undertaken was:—

(1) To secure purity of type.

(2) To obtain high yielding strains or lines, and

(3) To maintain the prolificacy of the varieties at their highest possible level.

The first object is achieved as the result of choosing a single plant as the "Unit of Selection." This was the unit previously adopted in New South Wales, and the natural corollary of the methods adopted under the guidance of the late Wm. Farrer for the production of new varieties by cross-breeding.

The adoption of such a unit ensures a sound foundation for the attainment of the first object, because the selection of a single plant as the starting point undoubtedly supplies a source free from admixture, being, as it is, the product of a single seed. The second objective is secured by selecting in the first place a number of plants —30 or more, of attractive appearance, and of good yielding quality. If the original test consists of more than thirty plants, the number is eventually reduced to thirty by trial. These plants are then subjected to further selective tests to demonstrate their ability to transmit their most desirable characteristics in their progeny. This is determined by ascertaining, by trial in the field, the average productivity of a definite number of plants, usually 100, and the progeny of each plant, and comparing the results with each other. This method of comparison is a modification of the "Centegener" method of W. M. Hays, of Minnesota, adapted to suit our conditions.

The plants grown for trial in these rows are called "Lines." A "Line" is defined as consisting of a number of plants grown from the seed produced by a single parent plant. The ground on which pure lines are grown is treated in the same way and under a similar rotation to that adopted for the main crops of the farm. No attempt is made to give them specially good environmental conditions. The desire is to have the tests made under rather more severe conditions than obtain under ordinary farm conditions.

As the result of a second selection, half the plants are eliminated, and a third test undertaken. In this test each two representatives or lines of the original parent line are grown, these two lines being known as a "Family." A "Family" being defined as a number of pure lines, each the progeny of the same parent, *i.e.*, of a plant belonging to the same pure line. The third selection consists of choosing the best six "families" from the fifteen used in the second later test. The fourth selection in which five lines belonging to each family are tried, reduces the number of families to three, and the fifth and final selection to one. This is the starting point of the pure "strain" or "race" aimed at. A strain is defined as a collection of "families" produced by seed obtained from the same source, and when each family constituting the strain can be traced directly to a common ancestral plant, the strain is said to be "pure" selected or "pedigree."

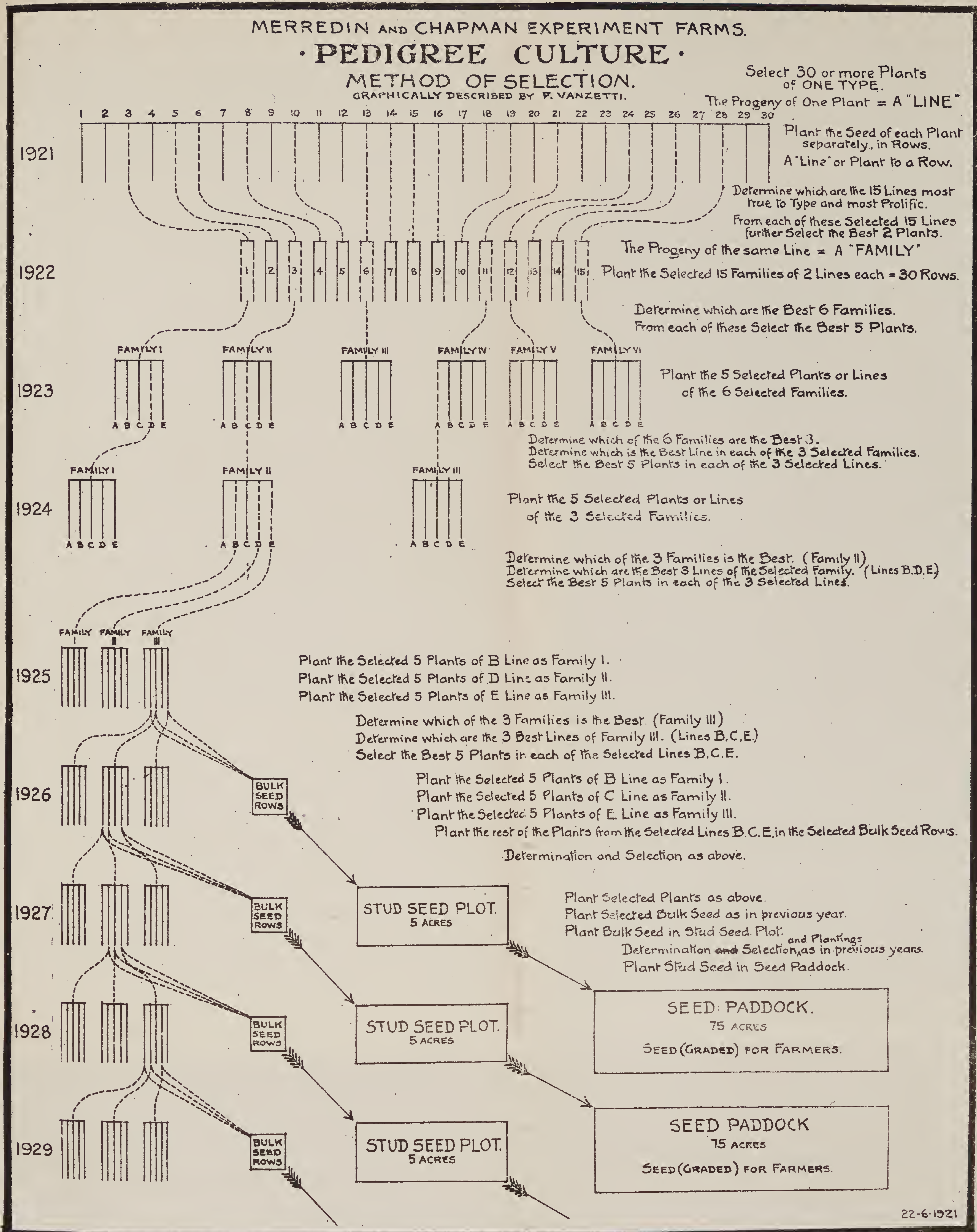
To achieve the third objective and to maintain the prolificacy of the strain at the highest level, the same system of selection is continued so as to choose each year the most prolific family. The three most prolific lines in that family are chosen to provide the families of the next generation. The balance of the seed is used to plant a "nursery" or "elite" plot, which in its turn provides from 30 to 60 rows and produces from 1 to 2 bushels. The seed from the "nursery" or "elite" plot is known as "selected bulk" seed, usually marked "bulk." This grain obtained from the "elite" plot, sown thinly with an ordinary farm seed drill, will plant 5 acres or more; the area so planted is called a "stud" plot, and the seed therefrom is known as "stud" seed. The produce of the "stud" plot—80 to 100 bushels—is utilised for planting the main crops of the farm, the produce of which, when graded, is the "pedigree" seed sold to farmers.

It may be thought that such a method would require a long time to grow enough seed for commercial purposes, but a little calculation will show that this is not the case. After the initial selections necessary in connection with a mixed strain have been made and the system of selection contracted to three related families, it is found that only four years elapse between the original selection and the production of seed on a commercial scale. This is shown in the accompanying diagram which has been arranged by my assistant, Mr. Vanzetti, to show, in a graphical form, the system in vogue at the Experiment Farms at Chapman and Merredin.

To avoid errors, and also to assist in detecting them when they occur, very definite instructions are laid down with regard to the method of carrying out the various operations. These details have been decided as the result of experience gained in past years, and are to be observed as rigidly and seriously as a sacred ritual.

So that an exact record may be secured of the plants sown and the tests made, the rows must be laid out systematically and in accordance with a well designed plan.

The area on which this pure line breeding is carried out is first divided into sections, 1 chain long with divisions or pathways be-


MERREDIN AND CHAPMAN EXPERIMENT FARMS.
·PEDIGREE CULTURE·
METHOD OF SELECTION.
GRAPHICALLY DESCRIBED BY F. VANZETTI.
Select 30 or more Plants of ONE TYPE.
The Progeny of One Plant = A "LINE"
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
1921
Plant the Seed of each Plant separately, in Rows.
A "Line" or Plant to a Row.
Determine which are the 15 Lines most true to Type and most Prolific.
From each of these Selected 15 Lines further Select the Best 2 Plants.
1922
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
The Progeny of the same Line = A "FAMILY"
Plant the Selected 15 Families of 2 Lines each = 30 Rows.
Determine which are the Best 6 Families.
From each of these Select the Best 5 Plants.
FAMILY I
FAMILY II
FAMILY III
FAMILY IV
FAMILY V
FAMILY VI
1923
A B C D E
Plant the 5 Selected Plants or Lines of the 6 Selected Families.
Determine which of the 6 Families are the Best 3.
Determine which is the Best Line in each of the 3 Selected Families.
Select the Best 5 Plants in each of the 3 Selected Lines.
FAMILY I
FAMILY II
FAMILY III
1924
A B C D E
Plant the 5 Selected Plants or Lines of the 3 Selected Families.
Determine which of the 3 Families is the Best. (Family II)
Determine which are the Best 3 Lines of the Selected Family. (Lines B.D.E.)
Select the Best 5 Plants in each of the 3 Selected Lines.
FAMILY I
FAMILY II
FAMILY III
1925
Plant the Selected 5 Plants of B Line as Family I.
Plant the Selected 5 Plants of D Line as Family II.
Plant the Selected 5 Plants of E Line as Family III.
Determine which of the 3 Families is the Best. (Family III)
Determine which are the 3 Best Lines of Family III. (Lines B.C.E.)
Select the Best 5 Plants in each of the Selected Lines B.C.E.
1926
BULK SEED ROWS
Plant the Selected 5 Plants of B Line as Family I.
Plant the Selected 5 Plants of C Line as Family II.
Plant the Selected 5 Plants of E Line as Family III.
Plant the rest of the Plants from the Selected Lines B.C.E. in the Selected Bulk Seed Rows.
Determination and Selection as above.
1927
BULK SEED ROWS
STUD SEED PLOT. 5 ACRES
Plant Selected Plants as above.
Plant Selected Bulk Seed as in previous year.
Plant Bulk Seed in Stud Seed Plot.
Determination and Selection, and Plantings as in previous years.
Plant Stud Seed in Seed Paddock.
1928
BULK SEED ROWS
STUD SEED PLOT. 5 ACRES
SEED PADDOCK. 75 ACRES
SEED (GRADED) FOR FARMERS.
1929
BULK SEED ROWS
STUD SEED PLOT. 5 ACRES
SEED PADDOCK 75 ACRES
SEED (GRADED) FOR FARMERS.
22-6-1921

tween them at the ends, 3 links wide. Each section is then divided into rows 2¼ links apart. The rows are numbered so that the one nearest the farm buildings is No. 1. The sections are distinguished by letters, the small letters of the arabic rotation, a, b, c, etc., being used for this purpose on the seed packet.

Before commencing to plant the seeds, the different rows and sections are measured off on the ground just as a draughtsman would mark them on a plan.

To facilitate locating the different rows, every tenth row in each section is marked with a labelled peg or plate. This plate has the sectional letter (in this case a capital letter) and the number, without the final cypher, on it. Thus the peg or plate on the 80th row in section b would be marked $\frac{B}{8}$. The families are distinguished one from the other by the Roman numerals I, II, III, in order of merit, commencing with one. The selected plants are distinguished by the capital letteers A, B, C, D, E, the choicest being A. When the system is established, the seed to be planted consists of five "lines" of three families for the purposes of the best comparison.

Under the methods adopted at the Chapman and Merredin Farms, the "lines" are sown in parallel rows instead of in plots planted draught-board fashion as under the Minnesota plan. Each row is one chain long, so that the one hundred plants constituting a line are each one link (8 inches) apart, with the first and last seeds half a link from the boundary lines of the section. This gives ample room for plant development and affords facilities for easy observation of the individual plants. In order to ensure that the plants be spaced uniformally at link intervals, the early practice was to place a chain measure in the shallow furrow opened up for the reception of the seed and place a seed at each link mark; later a toothed wheel was designed which made indentations 1¼ inches deep at intervals of one link apart, but now those planting the seed have become so expert that they can drop the seed with great accuracy without mechanical aids.

In order to afford easy access to the plants for examination the rows are 2¼ links (18 inches) apart. They were originally 2 links apart (16 inches), but the greater width has been adopted so as to permit the ground between the rows to be cultivated by horse-drawn implements. This inter-cultivation during the growth of the plants keeps the weeds down and prevents their interfering more with the growth of some plants than with others. This is important in view of the necessity for seeing that the conditions for comparison are as uniform as it is possible to make them; and in this connection, so as to afford the best conditions for comparison, all the lines of one family are not planted adjacent to each other, but similar lines of the different families in their order of merit are planted in adjacent